Weak Chaos and the "Melting Transition" in a Confined Microplasma System

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We present results demonstrating the occurrence of changes in the collective dynamics of a Hamiltonian system which describes a confined microplasma characterized by long--range Coulomb interactions. In its lower energy regime, we first detect macroscopically, the transition from a "crystalline--like" to a "liquid--like" behavior, which we call the "melting transition". We then proceed to study this transition using a microscopic chaos indicator called the \emph{Smaller Alignment Index} (SALI), which utilizes two deviation vectors in the tangent dynamics of the flow and is nearly constant for ordered (quasi--periodic) orbits, while it decays exponentially to zero for chaotic orbits as $\exp(-(\lambda_{1}-\lambda_{2})t)$, where $\lambda_{1}>\lambda_{2}>0$ are the two largest Lyapunov exponents. During the "melting phase", SALI exhibits a peculiar, stair--like decay to zero, reminiscent of "sticky" orbits of Hamiltonian systems near the boundaries of resonance islands. This alerts us to the importance of the $\Delta\lambda=\lambda_{1}-\lambda_{2}$ variations in that regime and helps us identify the energy range over which "melting" occurs as a multi--stage diffusion process through weakly chaotic layers in the phase space of the microplasma. Additional evidence supporting further the above findings is given by examining the $GALI_{k}$ indices, which generalize SALI (=$GALI_{2}$) to the case of $k>2$ deviation vectors and depend on the complete spectrum of Lyapunov exponents of the tangent flow about the reference orbit.

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